Global Warming, the Greenhouse Effect, and all that

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Probus Club of Sydney

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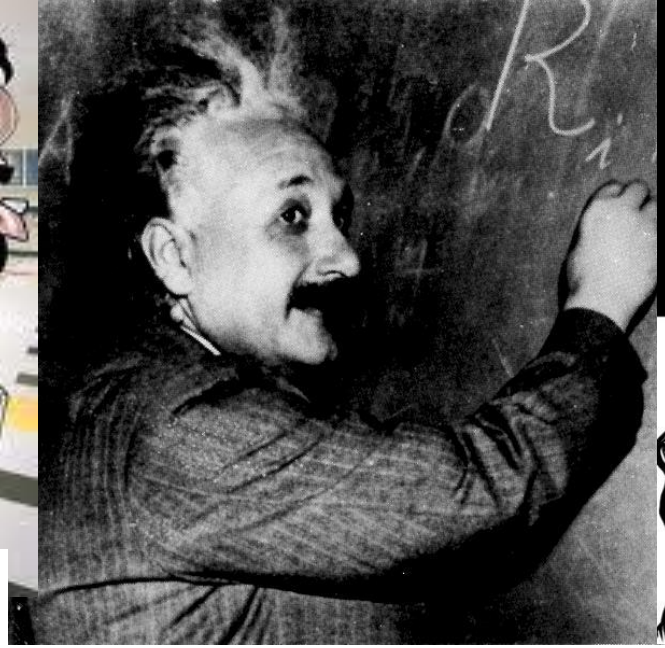
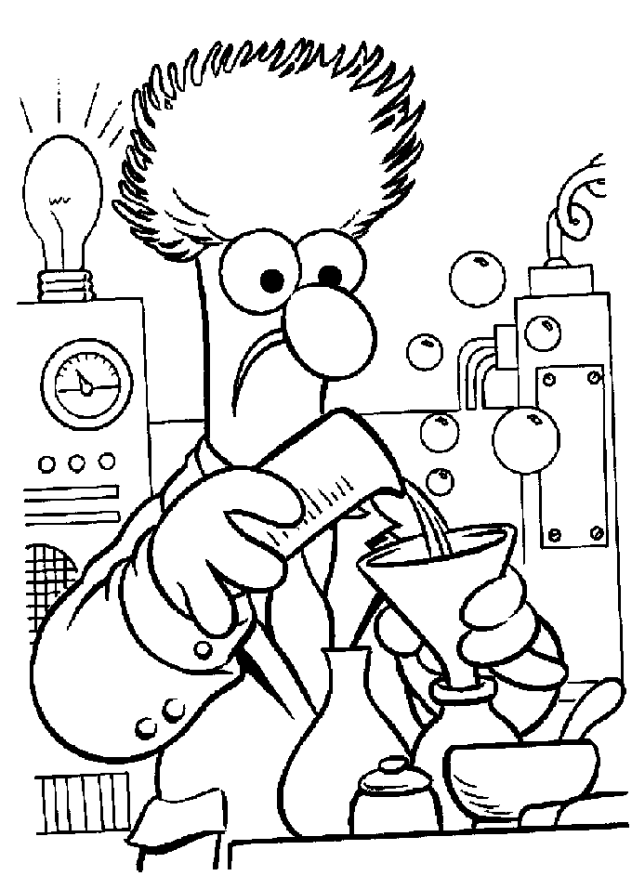
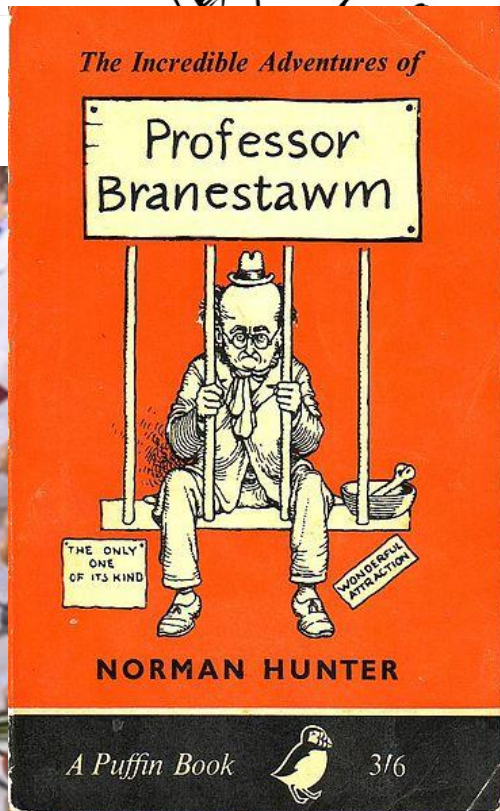
BIG QUESTIONS

- What is the greenhouse effect?
- Is the greenhouse effect changing?
- Is the earth warming?
- Is the sea level rising?
- **Is human activity affecting these things?**
- What should we do about it?
- Is all this a symptom of a larger problem?





Scientists


The Incredible Adventures of
Professor Branestawm
THE ONLY ONE OF ITS KIND
WONDERFUL ATTRACTION
NORMAN HUNTER
A Puffin Book
3/6

Generating new science

- Research
- Analysis
- Write-up
- **Peer review**
- Publication
- **Questioning**
- Revision
- More research……

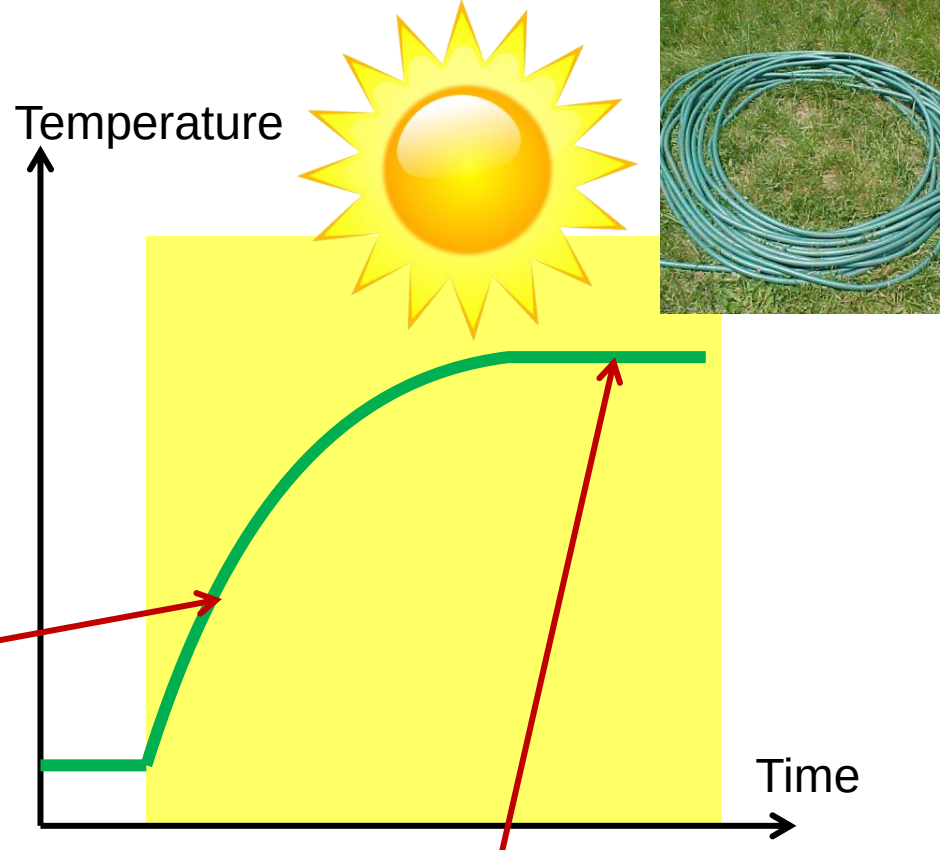
- This process is not perfect, but it is very reliable
- Also, scientific fraud is rare because most scientists value their integrity highly

A little Physics

How hot does a hose get when it is lying in the sun?

Energy balance

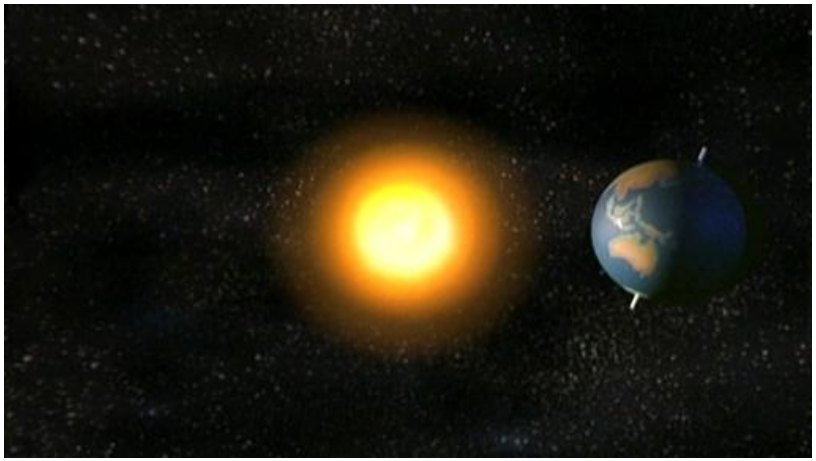
- An object that is put into the sunlight absorbs energy
- Its temperature therefore starts to increase
- As its temperature rises, it loses energy to the surroundings
- The rate of energy loss increases as the temperature increases

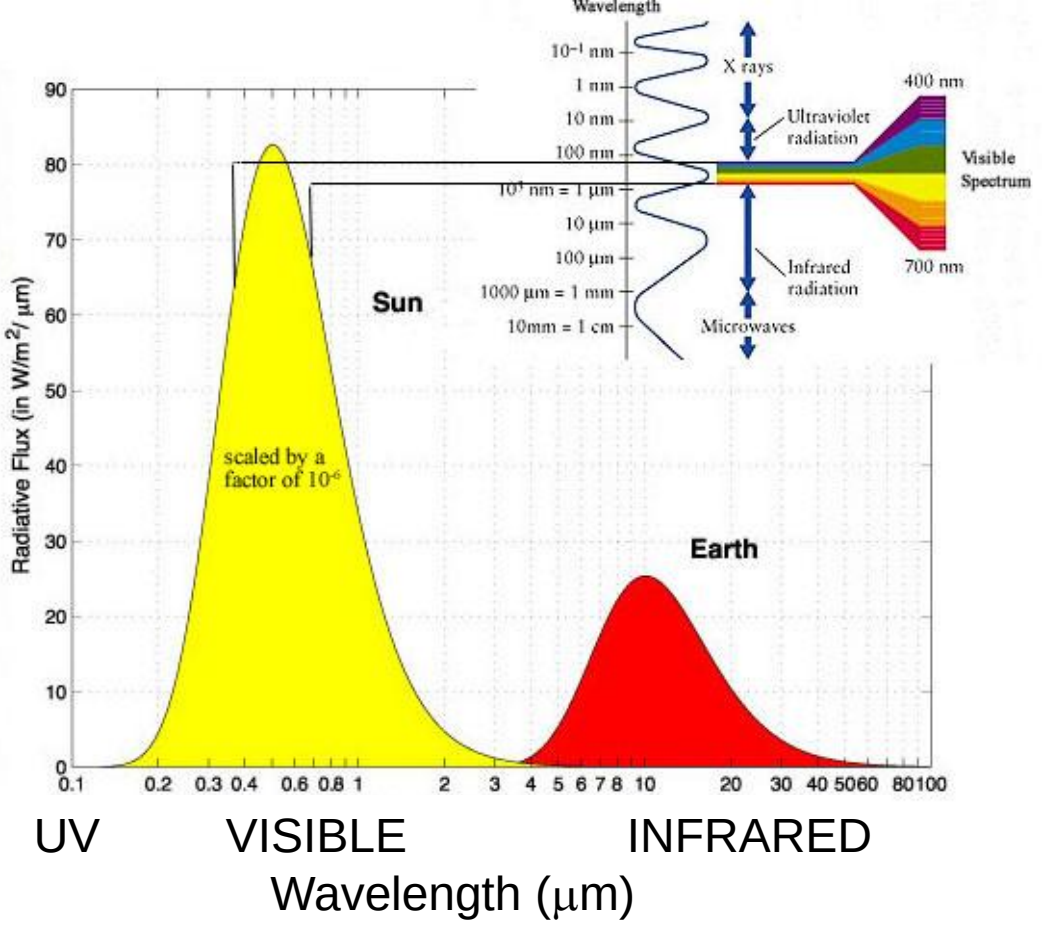


The temperature stabilises when:

Rate of energy absorption = **Rate of energy loss**

Energy balance for the earth

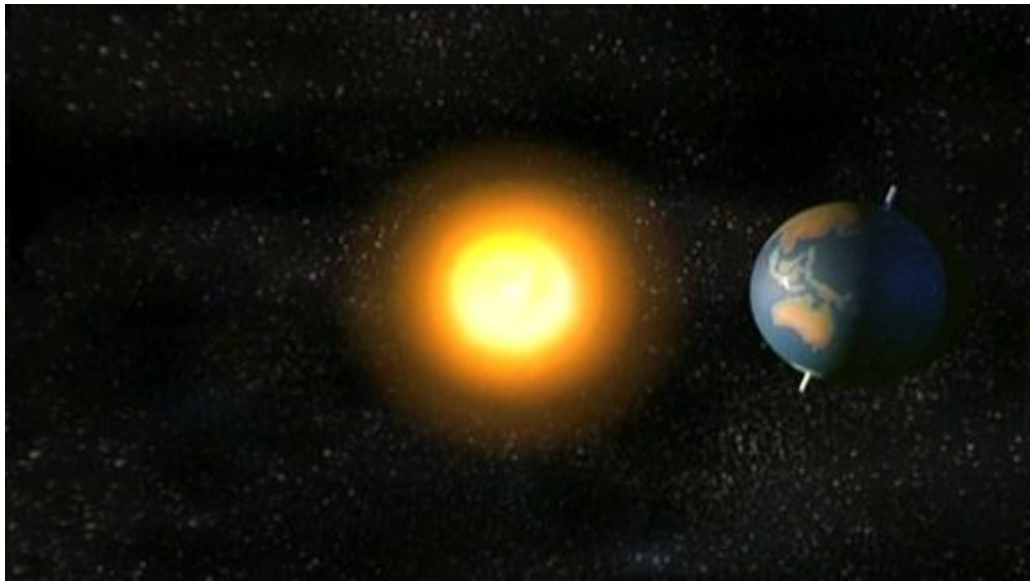




- The earth absorbs solar energy (mostly visible)
- The earth radiates thermal energy (infrared) to space
- The average temperature is stable when:

  rate of energy absorbed = rate of energy radiated

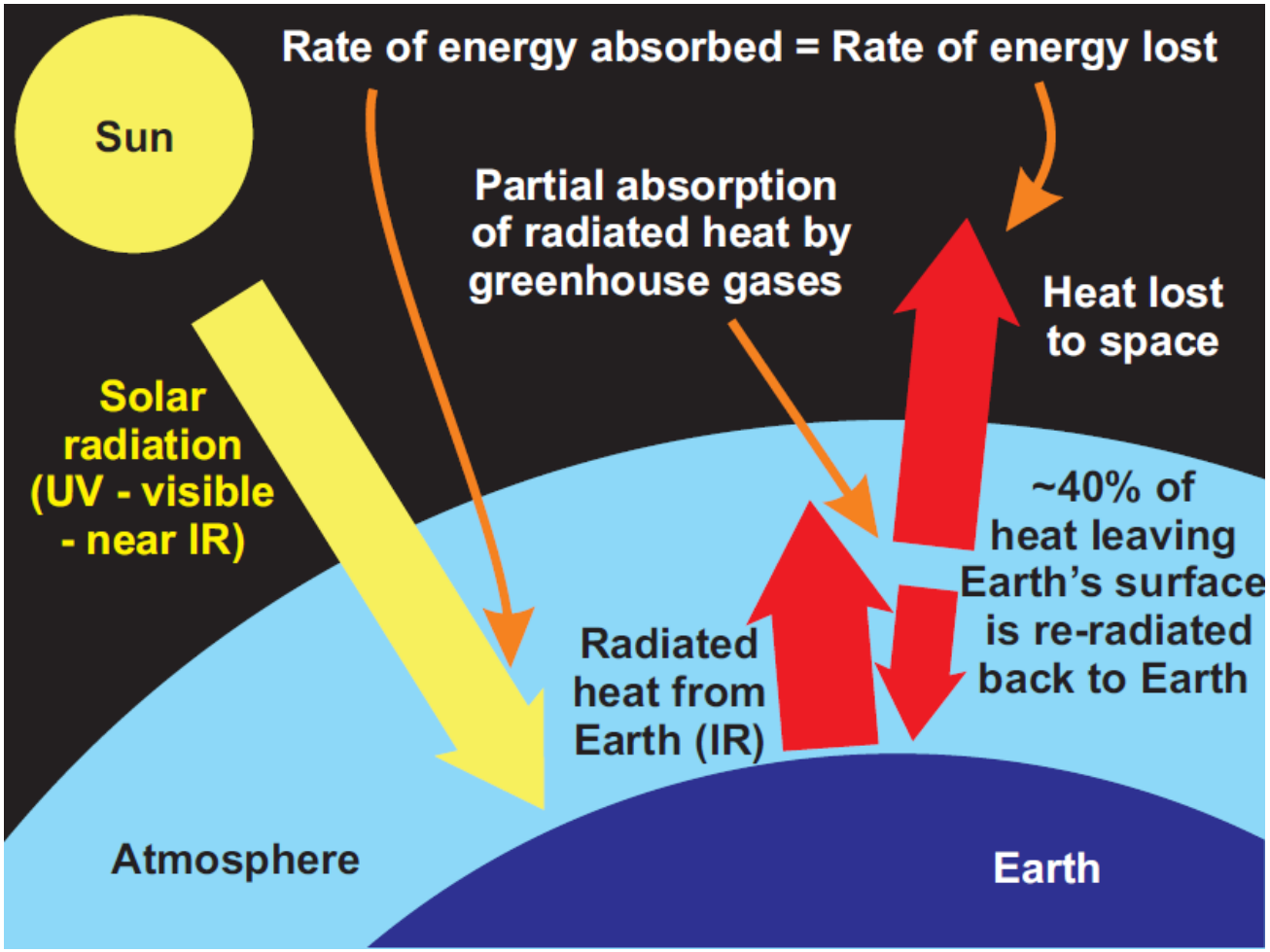
Energy balance for the earth



Without greenhouse gases, the stable (average) temperature of the earth would be about

-18°C

The Greenhouse Effect



The greenhouse effect increases the average surface temperature of the Earth from ~ **-18°C** to ~ **+15°C**, and makes the Earth habitable

Greenhouse gases

The significant greenhouse gases are:

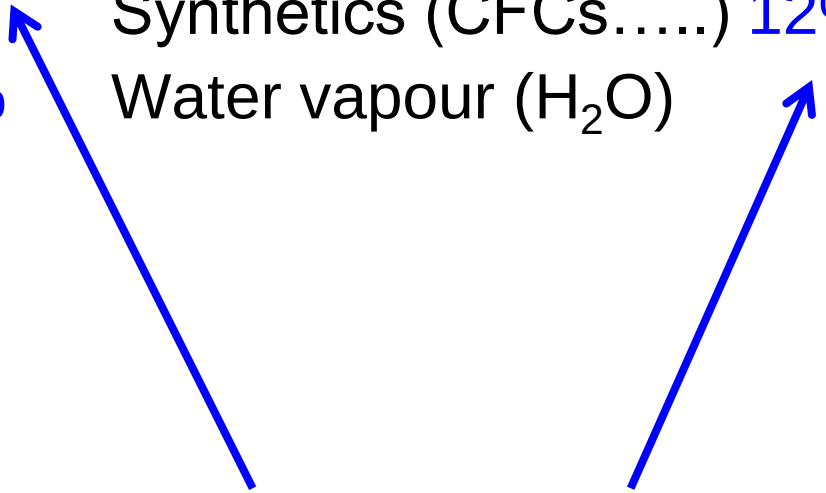
Carbon dioxide (CO_2) 64%

Methane (CH_4) 18%

Nitrous oxide (N_2O) 6%

Synthetics (CFCs…..) 12%

Water vapour (H_2O)



Greenhouse contributions from post-industrial gases

Carbon dioxide is produced when hydrocarbons are burnt

Hydrocarbon (C_nH_m) + Oxygen (O_2)

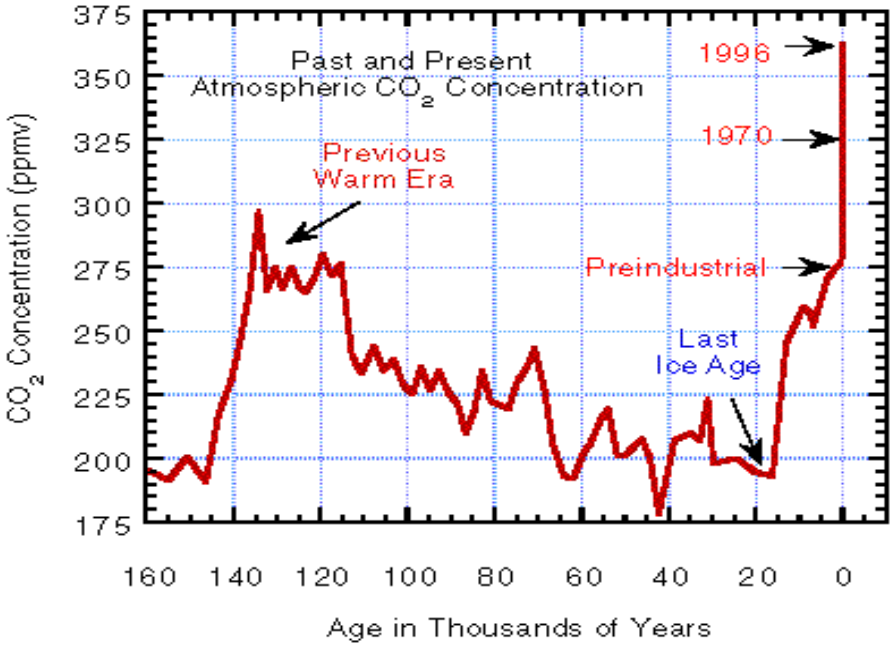
↓

Carbon dioxide (CO_2) + Water (H_2O)

+

ENERGY (HEAT)

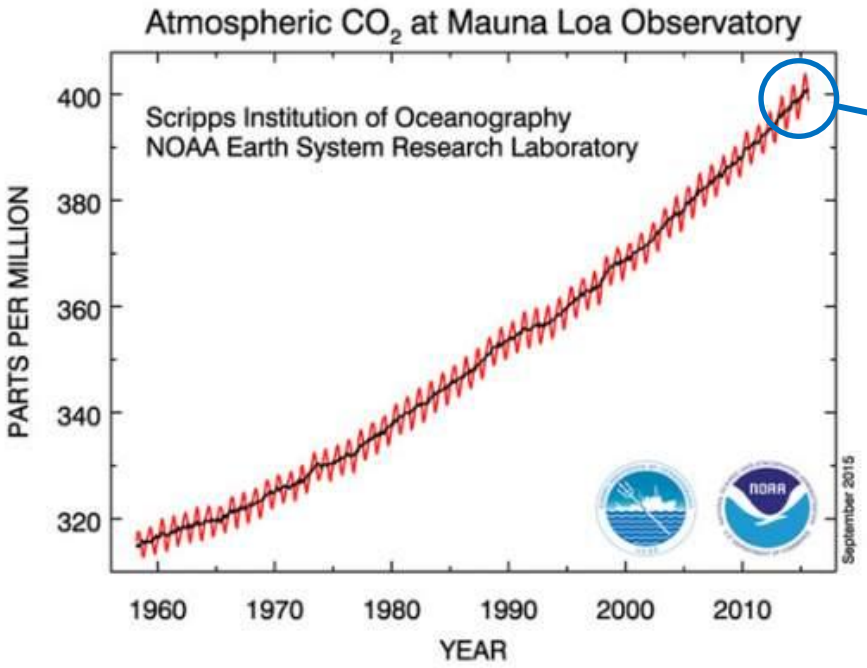
Deforestation is also a major source of atmospheric carbon dioxide

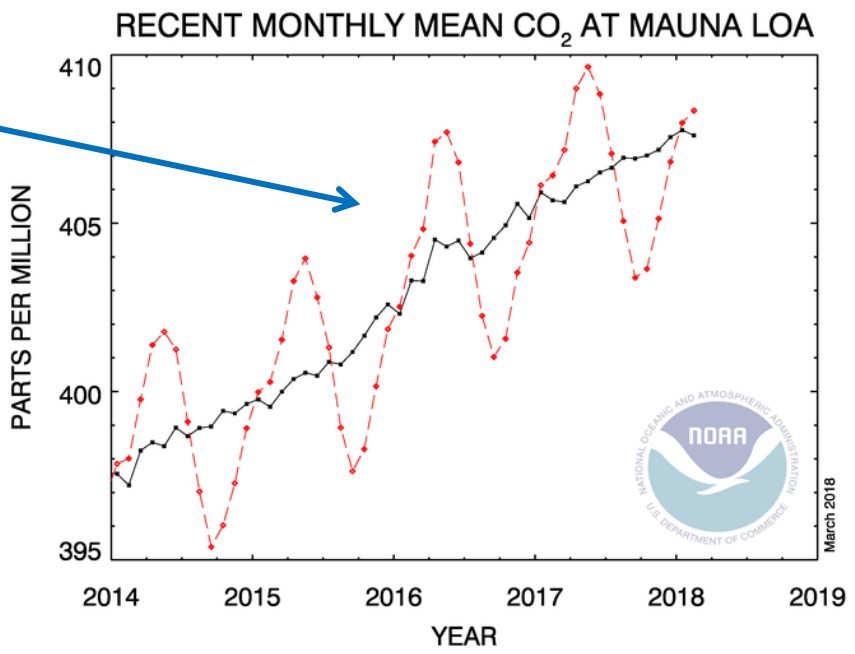


CO_2 concentrations

Past CO_2 concentrations have varied significantly

Present CO_2 levels are (historically) very high and **increasing rapidly**





Greenhouse effect - Conclusions

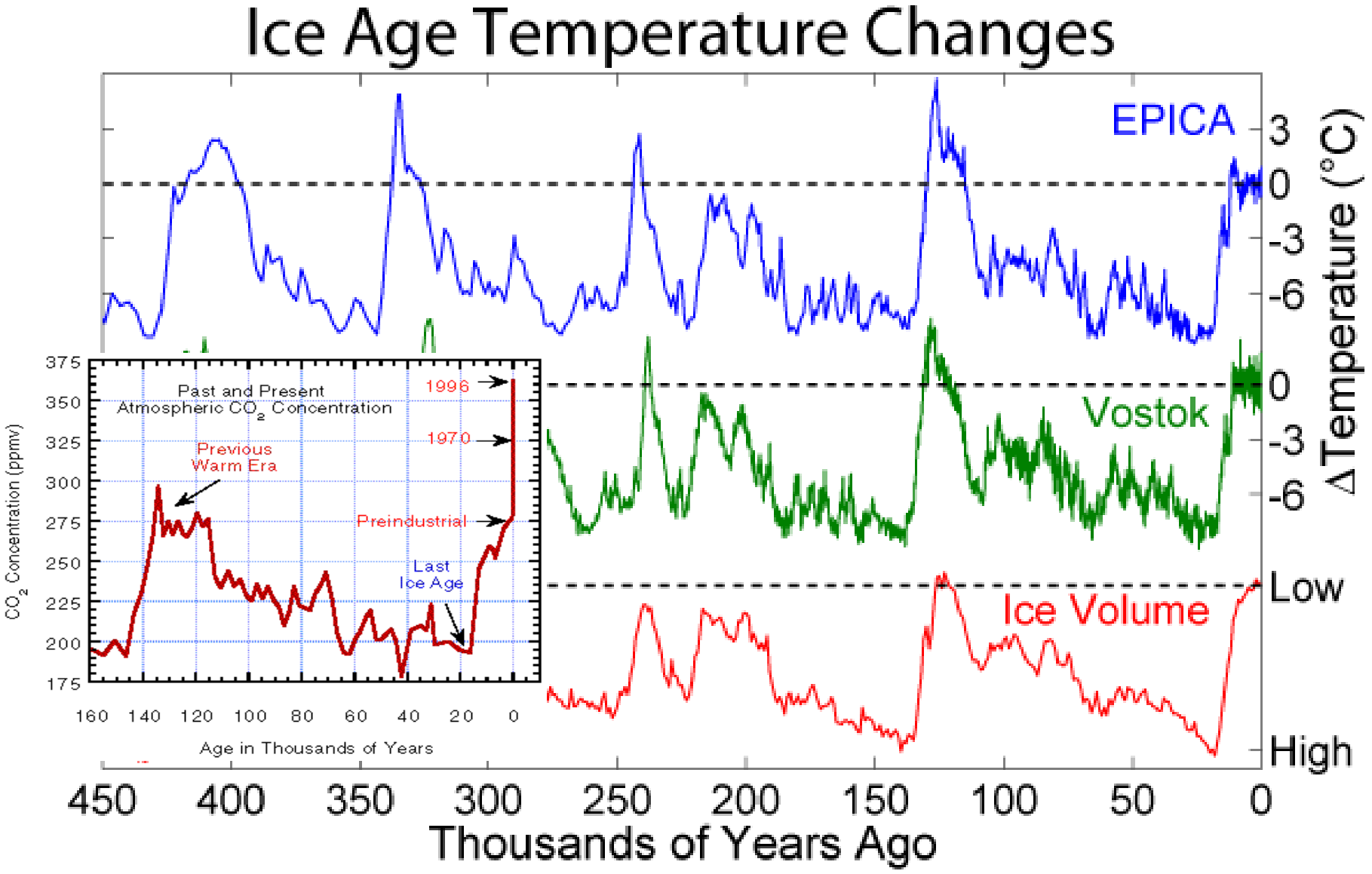
- The greenhouse effect is not new – without it the earth would not be habitable
- The most important greenhouse gas is CO_2
- The concentration of CO_2 is at historically high levels, and is increasing rapidly
- There is therefore no doubt that the greenhouse effect exists, and is increasing

Is the earth warming?

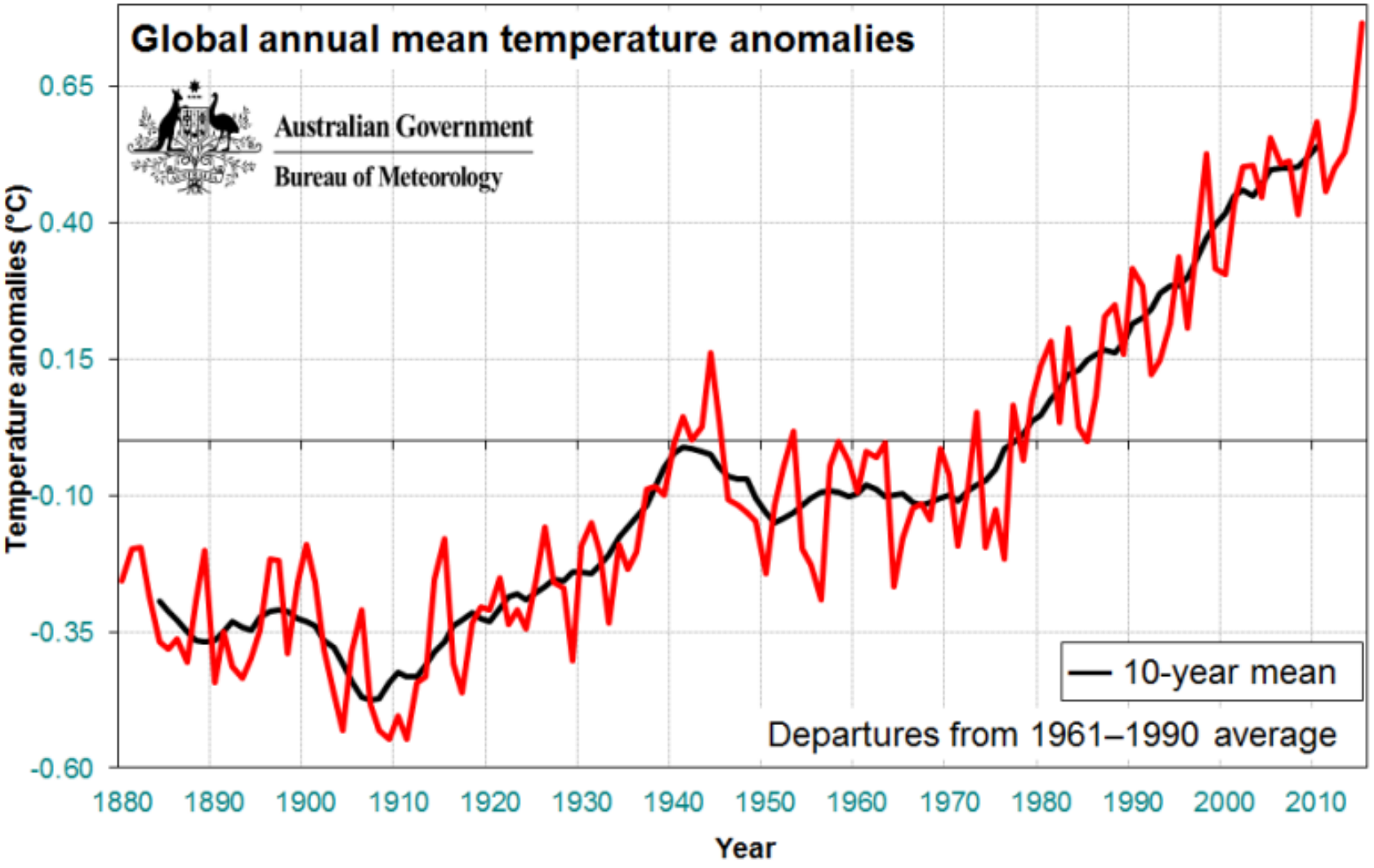
Is the earth warming?

This is a very difficult question, because:

- Solar input varies greatly
- Temperature changes are not uniform
- Huge energy flows from wind, ocean
- Volcanos, dust, land clearing affect temperature
- Cities create local “hot spots”
- Complex non-linear interactions



(EPICA – European Project for Ice Coring in the Antarctic)

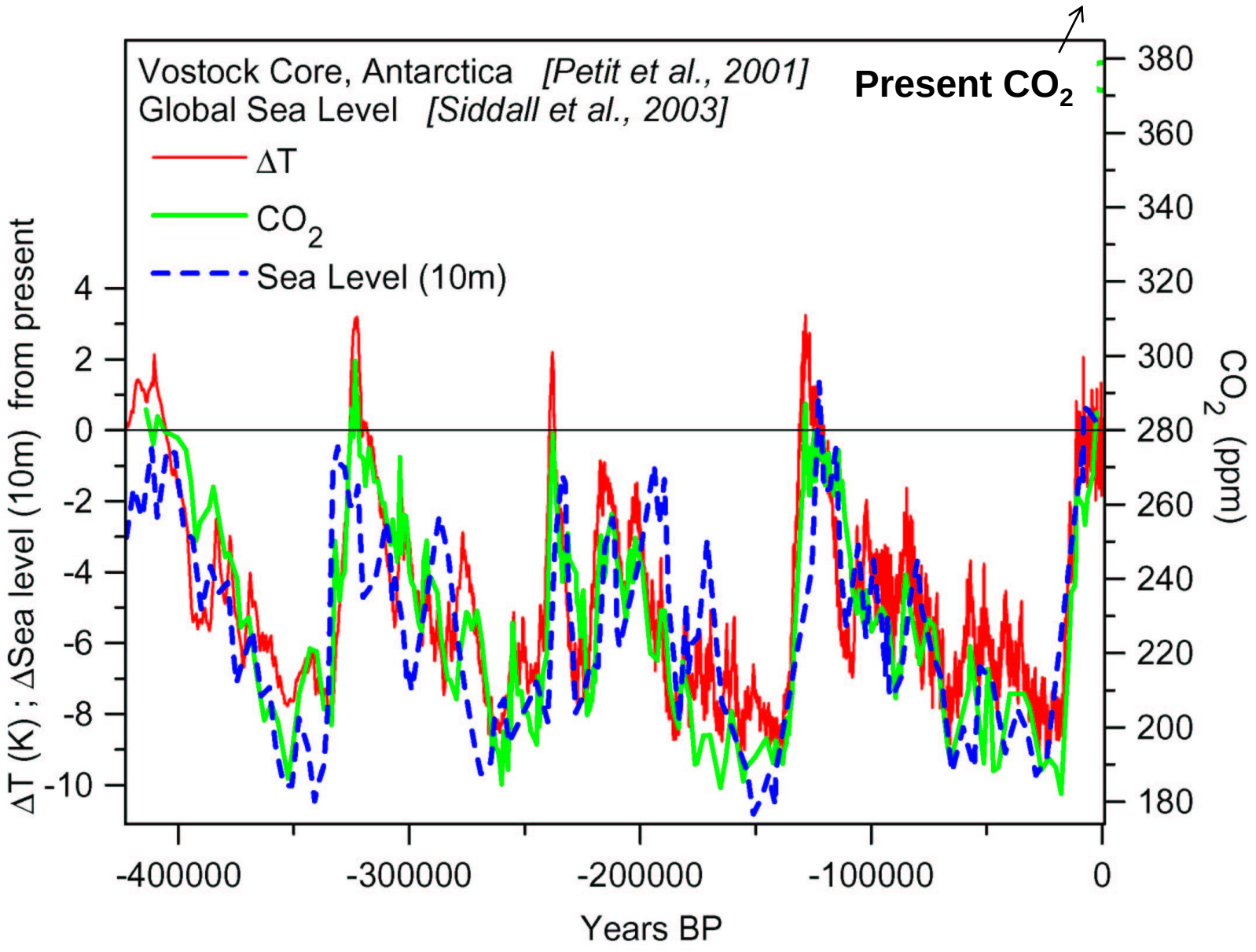

Global annual mean temperature anomalies
Australian Government
Bureau of Meteorology
Temperature anomalies (°C)
0.65
0.40
0.15
-0.10
-0.35
-0.60
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year
10-year mean
Departures from 1961–1990 average

Temperature - Conclusions

- The earth has experienced large temperature variations in the past
- These variations are highly correlated with ice ages, and with CO_2 concentration
- There is strong evidence that the earth's average temperature has been increasing quite rapidly for many decades

Is the sea level increasing?

Long term sea level data



Estimating sea level from tide gauge readings

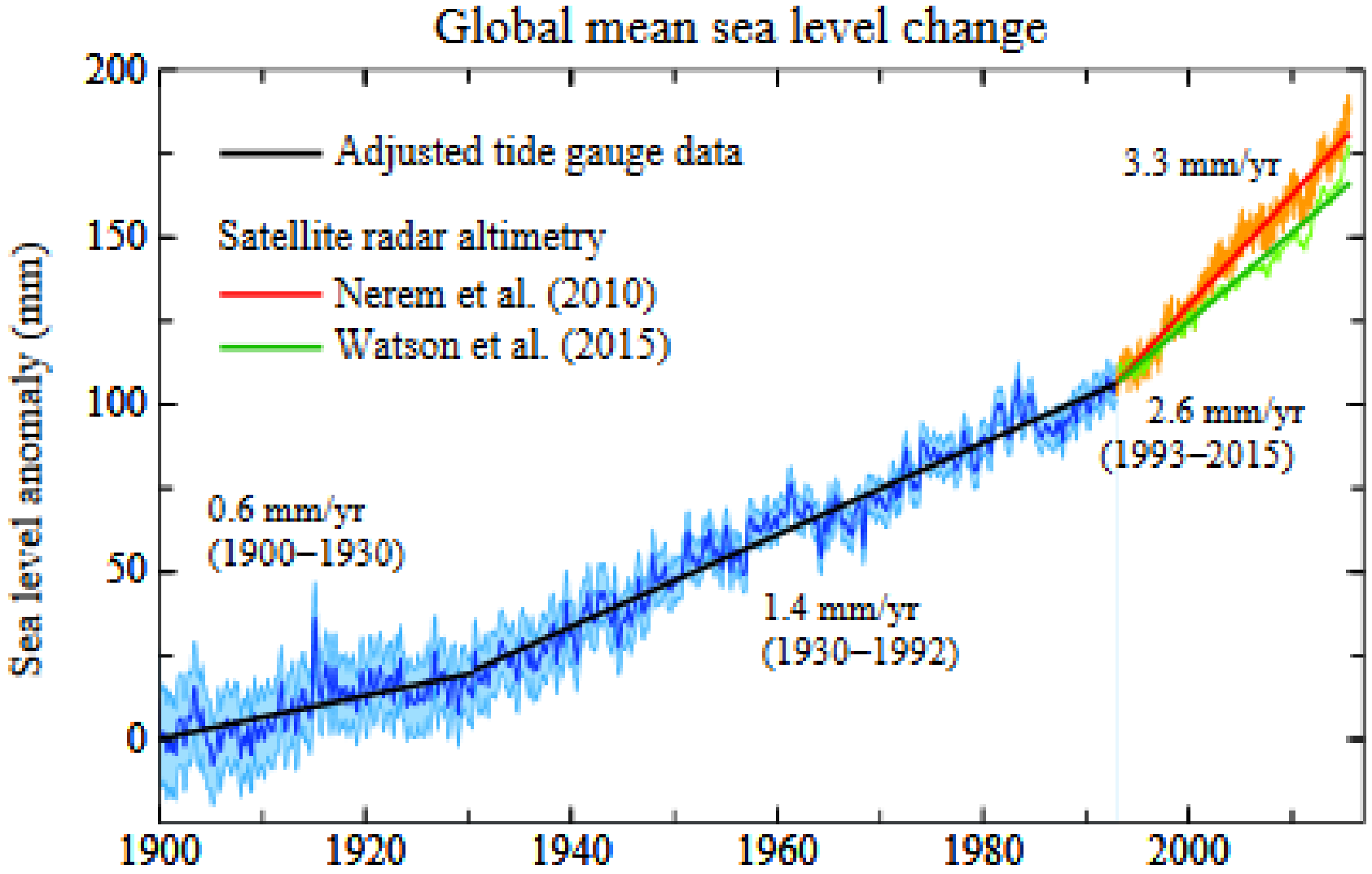
Sea level estimates from tide gauge readings can be affected by:

- Vertical movements of the earth's crust
- Cyclic variations in readings over decades

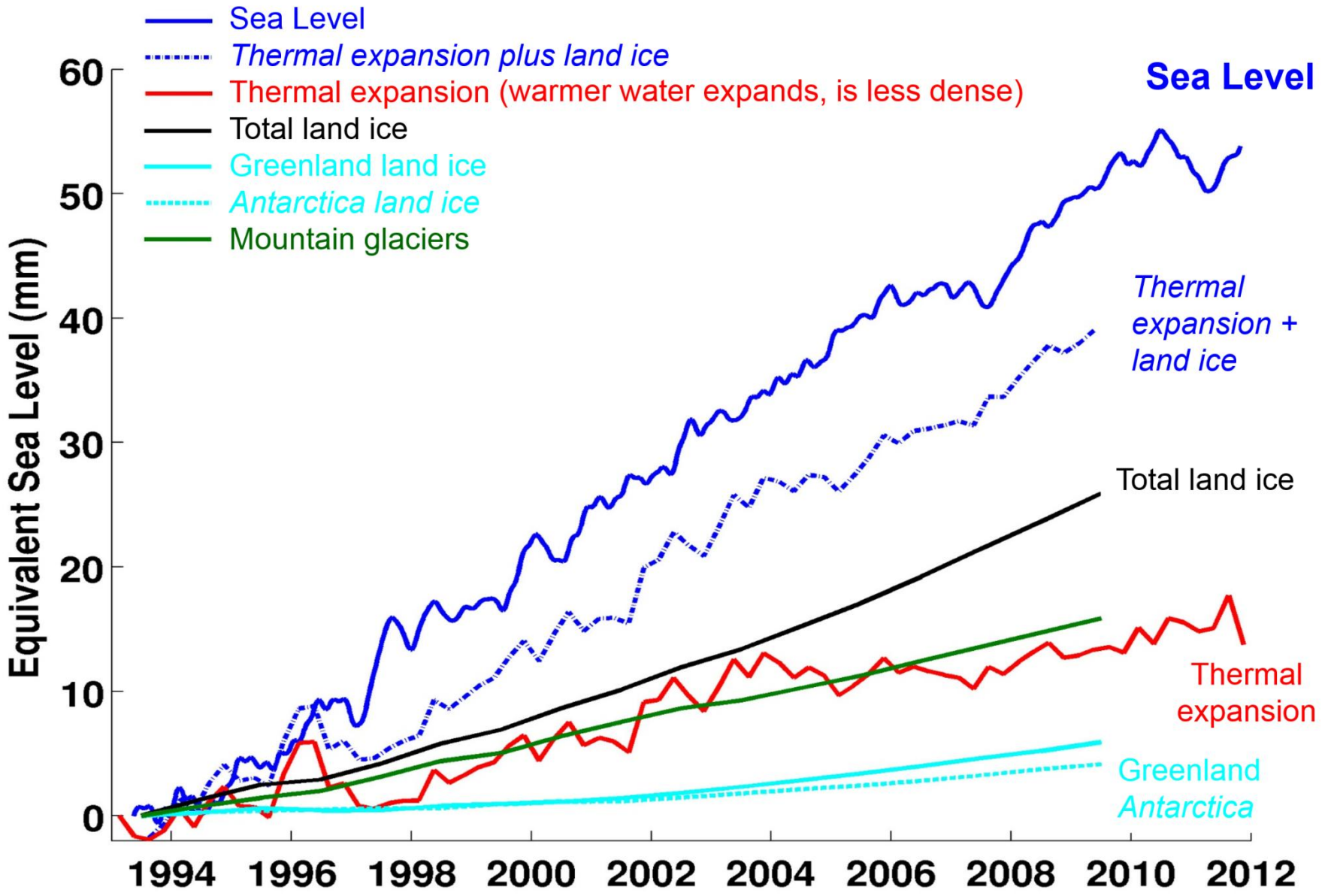
To be acceptable:

- Records > 60 years
- Data > 80% complete
- Close agreement with nearby tide gauges
- Measuring site away from the edges of tectonic plates
- Measuring site not affected by the last ice age

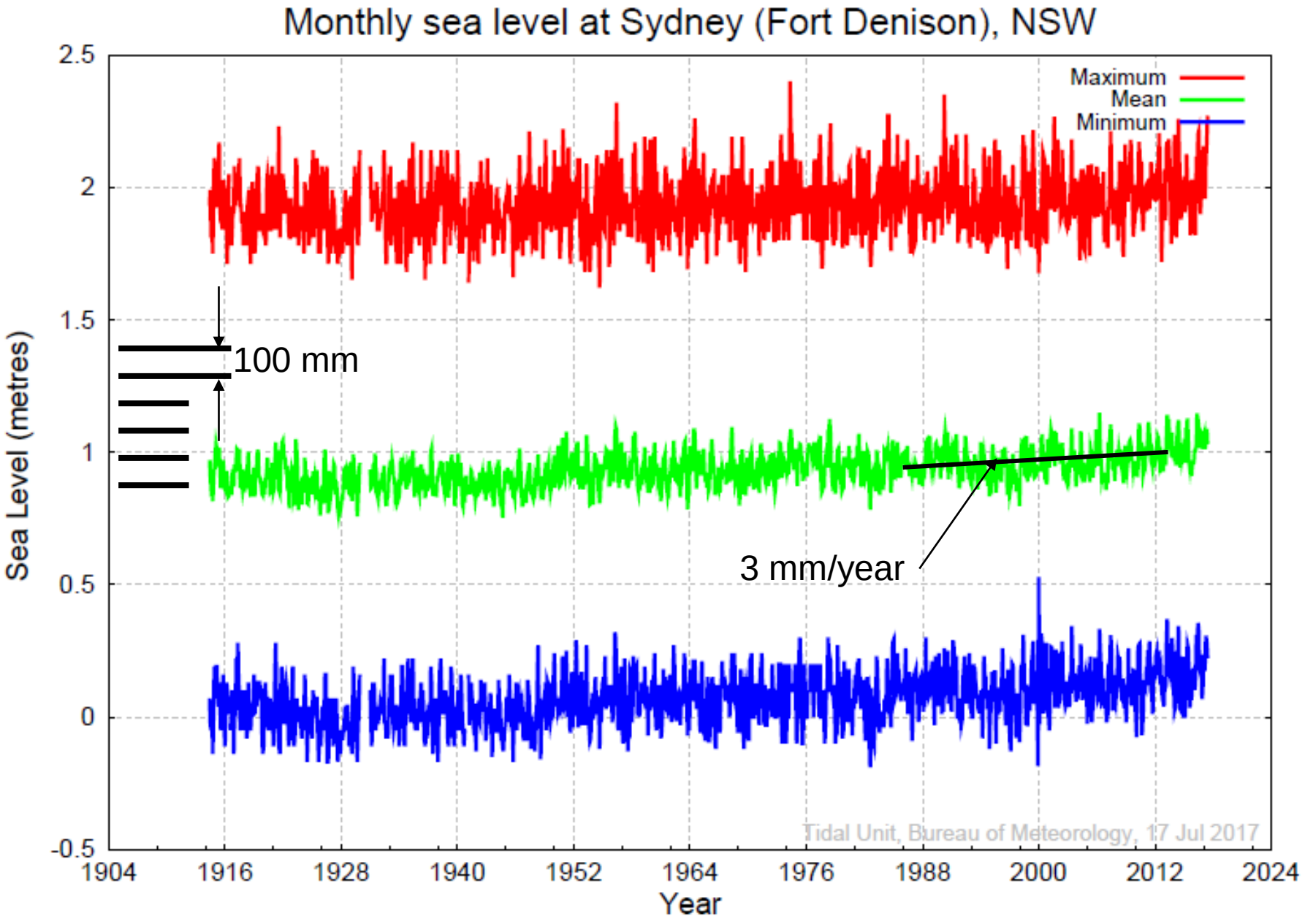
This is not the bloke to ask if the sea level has been rising over the past 30 years


Global mean sea level change
Sea level anomaly (mm)
200
150
100
50
0
1900
1920
1940
1960
1980
2000
Adjusted tide gauge data
Satellite radar altimetry
Nerem et al. (2010)
Watson et al. (2015)
0.6 mm/yr
(1900–1930)
1.4 mm/yr
(1930–1992)
2.6 mm/yr
(1993–2015)
3.3 mm/yr

Causes of Sea Level Rise



Local sea level can "appear" to drop if the land is rising faster (rebound from glacier weight)


Monthly sea level at Sydney (Fort Denison), NSW
Maximum
Mean
Minimum
100 mm
3 mm/year
Tidal Unit, Bureau of Meteorology, 17 Jul 2017
Sea Level (metres)
Year
2.5
2
1.5
1
0.5
0
-0.5
1904
1916
1928
1940
1952
1964
1976
1988
2000
2012
2024

Sea level rise - Conclusions

- Sea level has changed greatly (~100 m) in the past
- Past sea level data are strongly correlated with concentrations of CO_2, and with ice ages
- In ~1900, average rate of rise was ~1 mm/year
- The average rate of rise is now ~3 mm/year
- First impacts will be local, extreme events
- Mitigation strategies need to be local (such as the Thames Barrier), but:
- Sea level rise will have global impacts

Summary so far

- There is **no doubt** that
  - The Greenhouse Effect exists
  - CO_2 levels are increasing
  - The earth is warming, on average
  - The sea level is rising, on average
- All indications are that the these changes have been occurring **more rapidly recently**

The blame game

- Are the increasing temperatures and rising sea levels due to increasing CO_2?
- Is human activity causing CO_2 levels to increase?

- **Are we part of the problem?**

Most climate scientists think that the **increasing CO_2 levels** are accelerating the rate of global warming and of sea level rise

Why do they think that?

- Thermal physics

Most climate scientists think that the **burning of fossil fuels** is accelerating the rate at which CO_2 levels are increasing

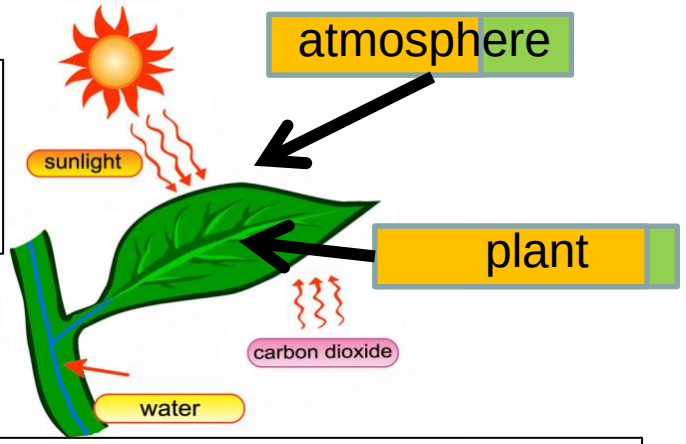
Why do they think that?

- Steady decrease in $^{13}CO_2/^{12}CO_2$ isotope ratio
- Oxygen depletion in atmosphere

C^{12}

C^{13}

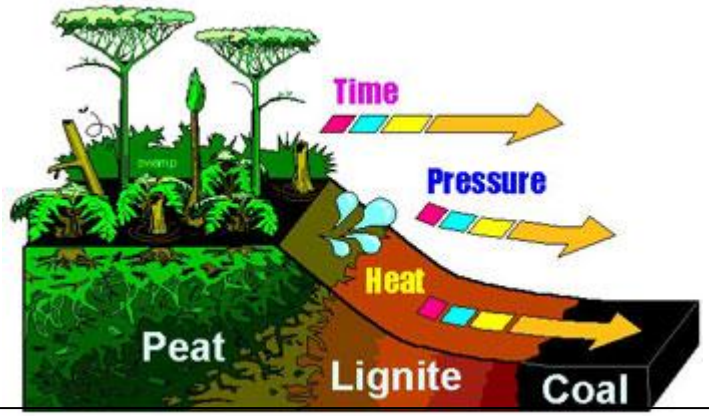
Carbon has two stable isotopes: C^{12} and C^{13}.
C^{12} and C^{13} are identical chemically.
C^{13} is slightly heavier than C^{12}.

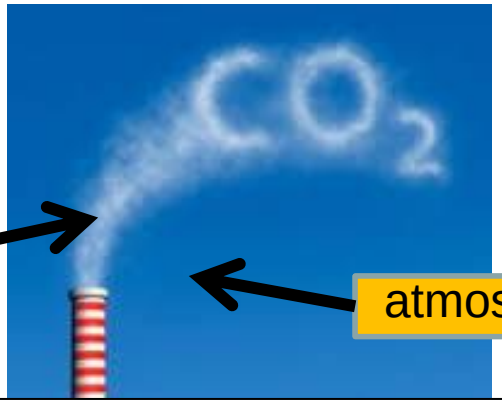


99% 1%

The atmosphere is mostly $C^{12}O_2$ with a little $C^{13}O_2$

Because C^{13} is heavier than C^{12}, $C^{13}O_2$ moves around less freely. $C^{13}O_2$ is therefore slightly less likely to be photosynthesised than $C^{12}O_2$





combustion

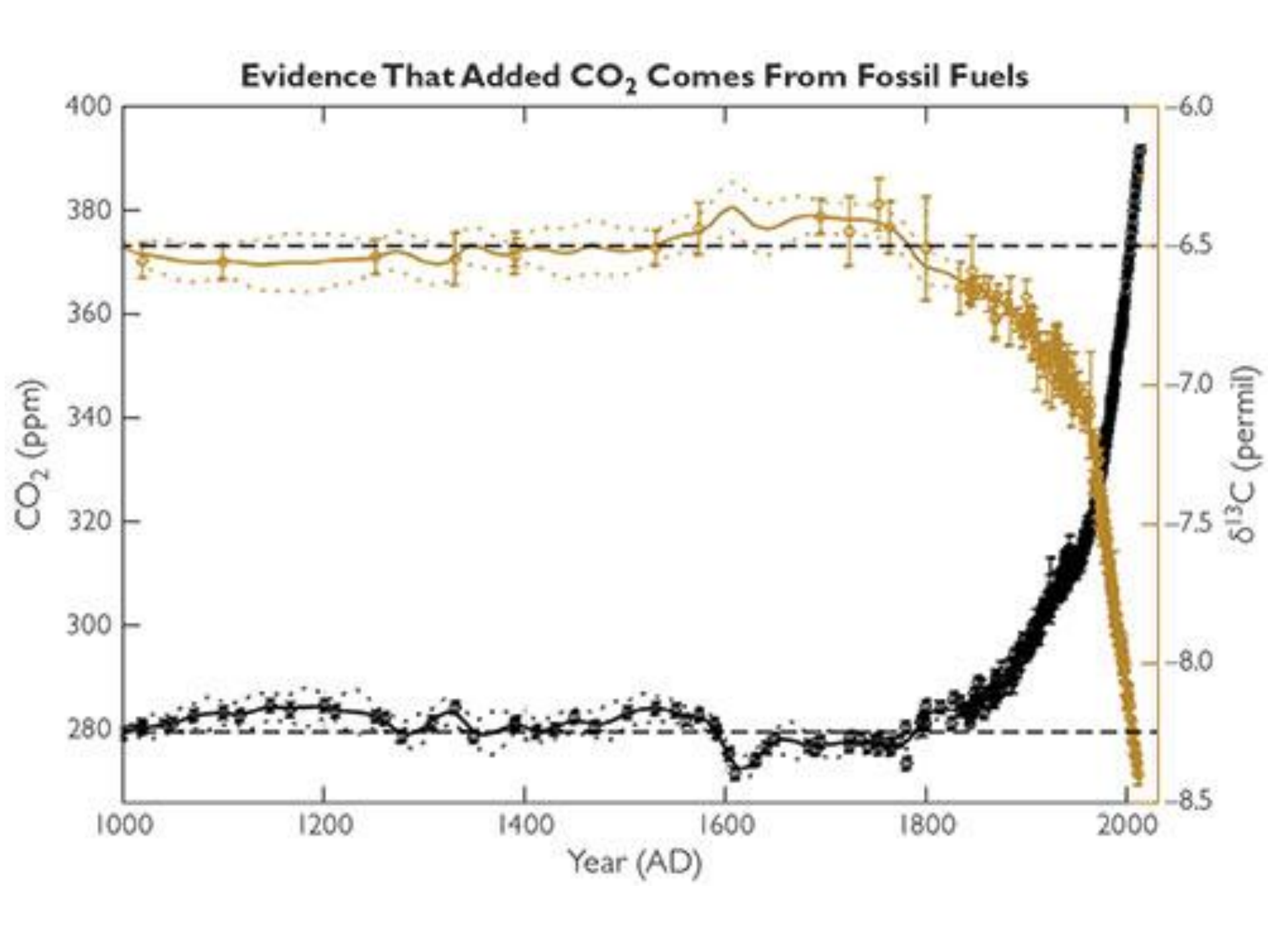
atmosphere

Fossil fuels, which are made from photosynthesised material, are thus slightly deficient in $C^{13}O_2$ compared with atmospheric CO_2

Burning fossil fuels therefore slightly reduces the proportion of $C^{13}O_2$ in the atmosphere

Fossil fuels

atmosphere


Evidence That Added CO_2 Comes From Fossil Fuels
400
380
360
340
320
300
280
CO_2 (ppm)
-6.0
-6.5
-7.0
-7.5
-8.0
-8.5
$\delta^{13}C$ (permil)
1000
1200
1400
1600
1800
2000
Year (AD)

Implication: Most climate scientists think that we are part of the problem

A useful reference

An excellent overview of climate change matters can be found in:

State of the Climate Report

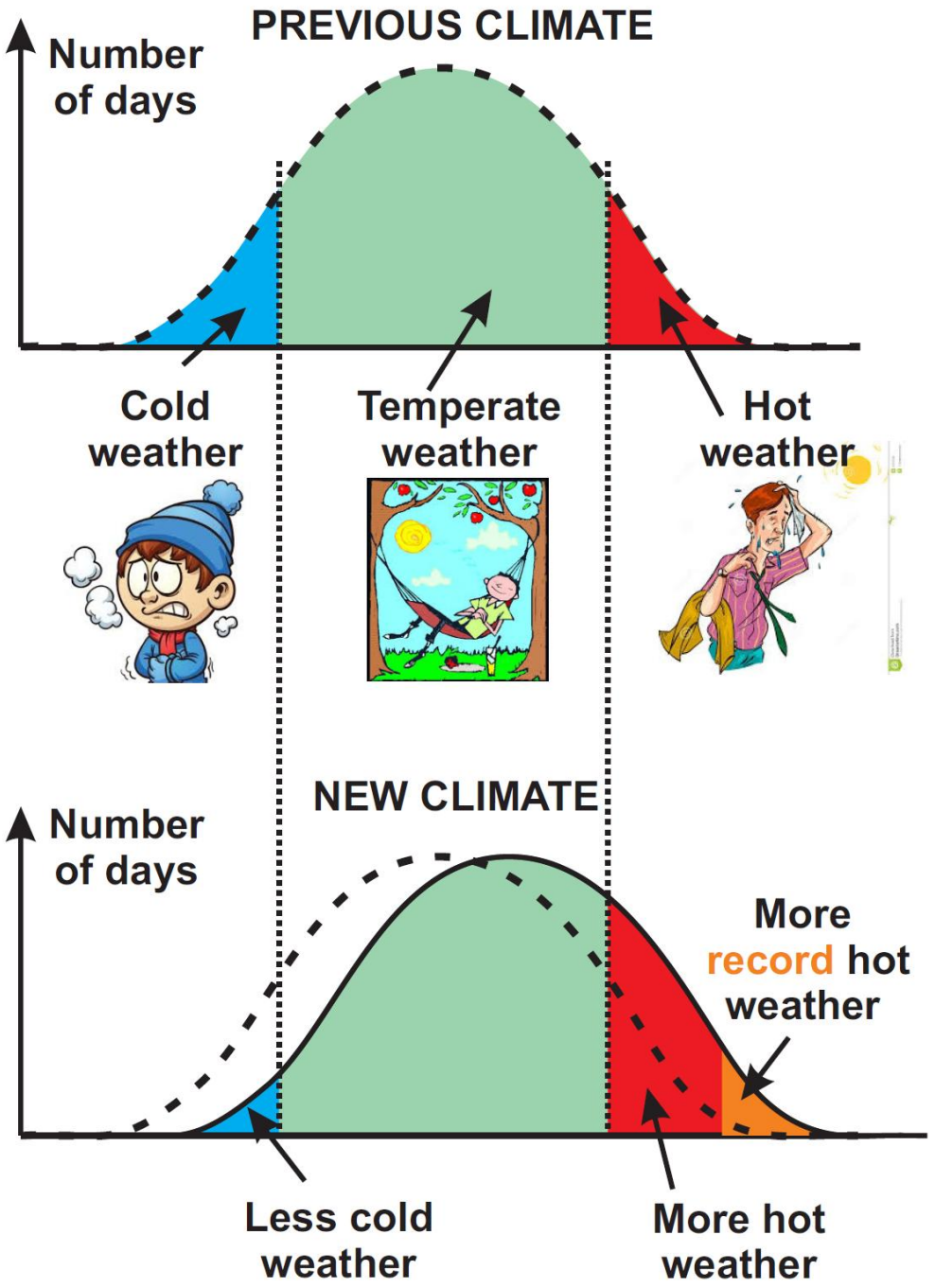
published each year by CSIRO and Australian Bureau of Meteorology

(Google “State of the Climate Report”)

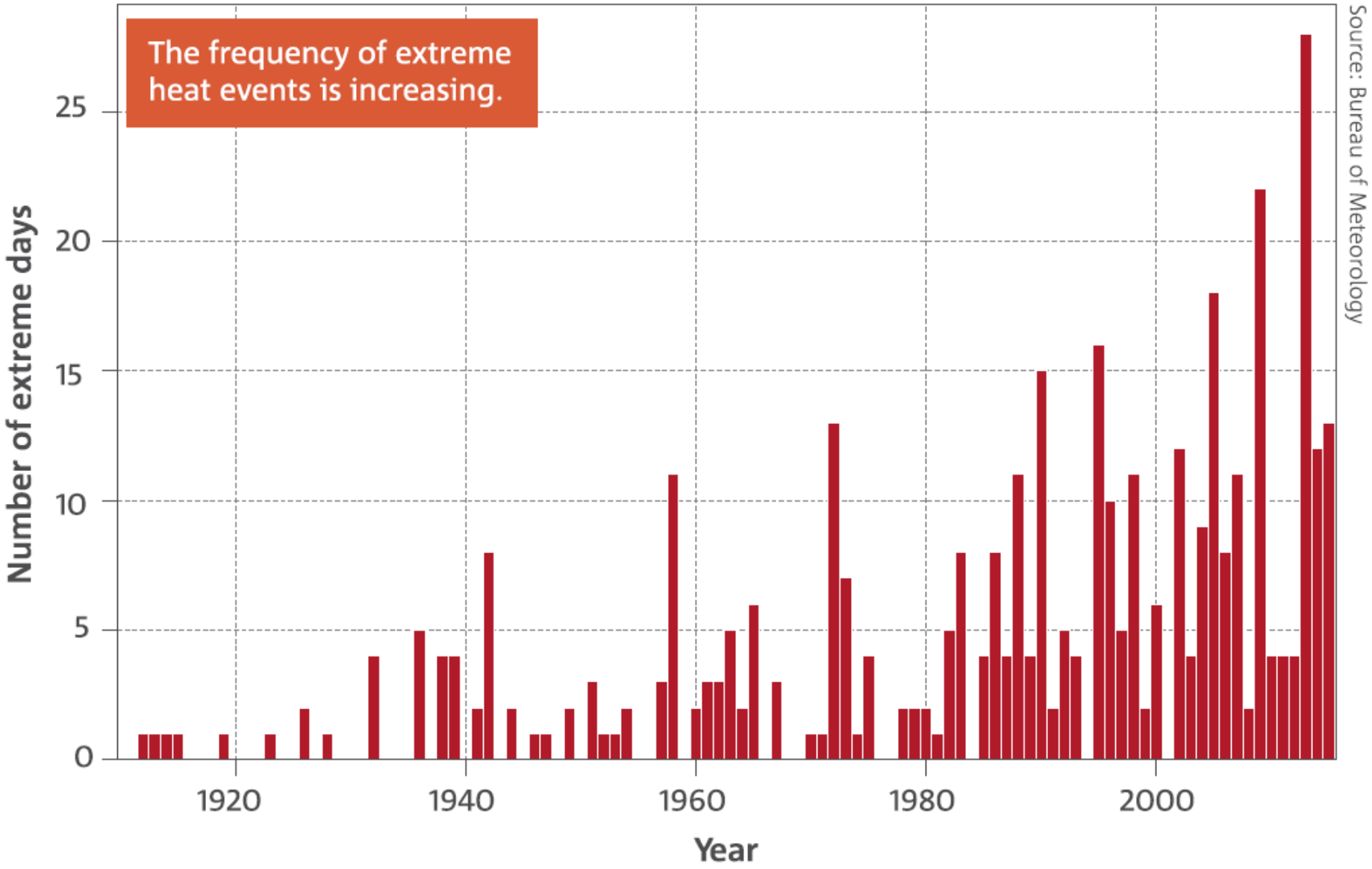
Why do some people deny the reality of climate change and our role in it?

- The climate has always been changing
- It is contrary to our personal experience
- The data are not straightforward to obtain
- The physics is not simple
- Some prominent scientists deny it
- The implications rely on complex modelling
- The implications are really bad news
- It is all too hard (living in denial)

Effect of climate change



Number of extreme heat events per year averaged over Australia
(Extreme = above 99th percentile for monthly average 1910-2015)



What are our options?

- Do nothing and hope for the best
- Implement local mitigation strategies
- Plan for a global humanitarian crisis
- Attempt to reduce our CO_2 emissions

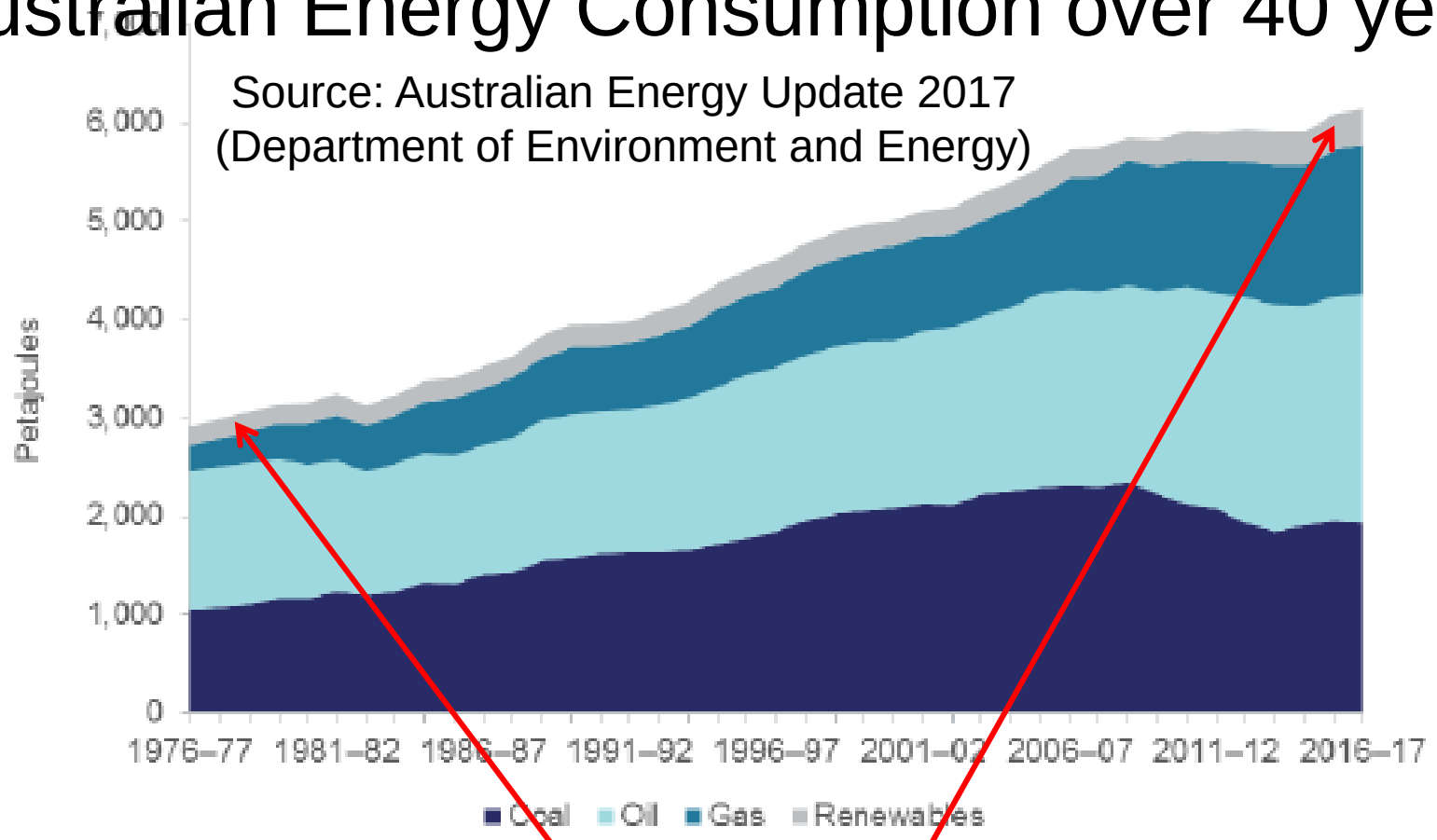
Reducing CO_2 emissions is an enormous challenge

- Huge reductions **(>50%)** in total CO_2 emissions are needed to have significant impact
- Most of the world emits much less CO_2 per person than the developed nations
- CO_2 emissions in the developing world will increase as their standard of living improves
- It is hypocritical for developed nations to insist that developing nations also emit less CO_2

The lessons of history

- **Reducing CO_2 is the latest energy crisis**
  - 1970s: Oil shocks
  - 1980s: Security of liquid fuels
  - 1990s onwards: Global warming
- Scientists have been trying to develop economic alternatives to fossil fuels for over 40 years
- Energy conservation helps, but is not enough
- At present, nuclear power is the only significant, economic, low CO_2 emission energy technology
- **Therefore, there is no quick, easy energy fix**

Australian Energy Consumption over 40 years



- Increase in energy consumption has slowed
- Renewables from ~6% to ~5% over ~40 years
- Wind is now 11% of renewables (zero in 1980s)
- Solar PV is now 5% of renewables (zero in 1980s)
- Renewables are now 15% of electricity generation

What if the climate scientists are wrong?

Let's get personal

- I believe that the world is using natural resources at an unsustainable rate
- I believe that strategies aimed at reducing CO_2 emissions will also reduce the impact of humans on the overall environment
- **I also believe that continual (exponential) economic growth and reducing CO_2 levels are incompatible**

THE REALLY BIG CHALLENGES

- Eliminate the need for continual economic growth
- Improve the standard of living of those less fortunate than us
- Decrease the population of our planet

The earth is worth saving